Commentary

Simon Gilchrist

Dan Thornton has written a very interesting paper on estimating the liquidity effect at the daily frequency. The paper starts with a nice discussion of the historical origins of the term "liquidity effect" (tracing it back to Milton Friedman, but somewhat surprisingly, no farther). The paper then discusses ways to identify the liquidity effect in daily data, and applies this discussion to critique the recent methodology of Hamilton (1997). The paper finds that the Hamilton results are not robust across sample periods and appear to be sensitive to outliers. Finally, the paper proposes an alternative way to estimate the liquidity effect via the relationship between nonborrowed reserves and the target funds rate. Here the paper has mixed success. Some variables seem highly correlated in the appropriate way, but the basic relationship between nonborrowed reserves and the target federal funds rate appears fragile—often it is insignificant, and sometimes it is the wrong sign.

In my discussion, I intend to provide a brief overview of the literature on liquidity effects, followed by a very simple exposition of a model along the lines of the one presented in the paper. I use this model to illustrate the basic arguments in the paper, and then by changing the assumption regarding the relationship between the Open Market Desk's (OMD) operating procedure and the desired level of nonborrowed reserves, I argue that we may have reason to expect biased and econometrically fragile parameter estimates from the nonborrowed reserves equation that is estimated in the paper.

The modern macroeconomic literature on liquidity effects can be divided into two separate strands: the theoretical literature that examines whether the current generation of dynamic general equilibrium models can generate a liquidity effect in response to innovations in money growth rates, and the identified vector autoregression (VAR) literature which examines whether there exists a contemporaneous negative relationship between money and nominal interest rates in response to monetary policy innovations. In the theoretical literature there are two types of models that are capable of generating a liquidity effect: limited participation, cash-in-advance models with heterogeneous agents; and sticky-price models that generate a demand for real balances through a transactions demand for money or, equivalently, money in the utility function. In both types of models, the theoretical difficulty with generating a liquidity effect stems from the fact that, with positively autocorrelated money growth, a rise in money growth today leads to anticipated inflation. Such anticipated inflation tends to push the nominal interest rate up rather than down, even if the real interest rate is falling in response to the innovation in money growth. Under certain parameterizations, either model may deliver a liquidity effect. Such parameterizations often involve imposing restrictions on quantity responses, either through inflexible production—as in the recent example of Christiano and Eichenbaum (1995)—or through the use of substantial curvature of the transactions benefits associated with real balances, combined with a limited response of interest-sensitive components of spending such as investment. In these frameworks, the response of money-demand to interest rates is a key model parameter that helps determine the liquidity effect.

The second strand of this literature using identified VARs to estimate the liquidity effect in time series data also has mixed success, with results depending on specification, sample period, and methods of identification. The problem here is that the assumptions required to identify monetary policy innovations and, hence, the liquidity effect in this literature are not necessarily valid; for example, the specifications considered by Bernanke and Blinder (1992) and Christiano and Eichenbaum (1992) both deliver liquidity effects by imposing the assumption that monetary policy does not have contemporaneous effects on output or prices. Avoiding these types of restrictions motivates Hamilton's use of daily data and his search for a valid instrument. Let me discuss this methodology by considering a simple version of Thornton's model for the daily federal funds market.

A SIMPLE MODEL OF THE FEDERAL FUNDS MARKET

I assume that demand for total reserves depends negatively on r_t, the current overnight federal funds

Simon Gilchrist is a professor of economics at Boston University.

rate, and positively on v_t^d, an i.i.d. shock to reserve demand

$$TR_t^d = -\lambda r_t + v_t^d. \tag{1}$$

For simplicity, I abstract from discount-window borrowing and assume that total reserves supply depends on B_t, the current level of nonborrowed reserves, and v_t^s, an i.i.d. shock to reserve supply:

$$TR_t^s = B_t + v_t^s. \tag{2}$$

Monetary policy is specified through the relationship between B_t^*, the desired level of nonborrowed reserves, and $\bar{r}_t$, the target level for the federal funds rate. In particular, B_t^* is chosen as in Thornton's model so that expected reserve supply equals expected demand at the target rate of interest:

$$B_t^* = -\lambda \bar{r}_t. \tag{3}$$

Lastly, following Thornton, I specify the relationship between the actual and desired level of nonborrowed reserves, B_t^*:

$$B_t = B_t^* + \omega_t, \tag{4}$$

where ω_t represents control error which is assumed to be i.i.d. Equation (4) may be thought of as the OMD's operating instructions given its desired level of reserves B_t^*. Here, the Trading Desk chooses desired reserves to minimize the error between actual and desired reserves on a daily basis. Equating supply and demand and applying equations (3) and (4), we obtain the reduced form equation for the federal funds rate as a function of the target rate and the i.i.d. shocks to demand and supply

$$r_t = \bar{r}_t - \frac{1}{\lambda}\left(B_t - B_t^*\right) + \frac{1}{\lambda}\left(v_t^d - v_t^s\right) \tag{5}$$

$$= \bar{r}_t + \frac{1}{\lambda}\left(v_t^d - v_t^s - \omega_t\right). \tag{6}$$

In this simple model, Hamilton's procedure reduces to a regression of the federal funds rate on the target rate and v_t^s an observable component of the shock to supply (the forecast error in Treasury balances). The coefficient on v_t^s allows one to identify the slope of the demand curve λ. Given inelastic supply, we only need one reduced form equation to identify λ. In Thornton's more general model, the supply curve is an upward-sloping function of the federal funds rate through the supply for borrowed reserves. In this case, as in Hamilton, we would need to estimate the reduced form for both the price and quantity equation to identify λ.

Thornton's critique of Hamilton is two pronged. The first prong of criticism is directed at the Treasury balance forecast error constructed by Hamilton. This variable was constructed using a VAR forecasting system. By obtaining the actual forecast errors made by the Board of Governors and the Treasury, Thornton notes that the VAR-based error has substantially higher variance, suggesting, unsurprisingly, that the VAR-based forecast error does not use all information available to the Federal Reserve and is thus subject to measurement error. Pure measurement error would lead to a downward bias in the coefficient estimate of $(1/\lambda)$ and hence upward bias in the estimate of λ itself. To the extent that the difference between the two forecast errors reflects information that is used to set monetary policy, the VAR-based error is no longer a valid instrument. These arguments strike me as reasonable, and the paper makes a valuable contribution to the literature by documenting and discussing such distinctions.

The second prong of criticism is directed at the robustness of Hamilton's findings. By collecting a larger data sample unavailable to Hamilton at the time, Thornton examines the robustness of Hamilton's findings across sample periods. Unfortunately, the liquidity effect only appears in the middle period that reflects Hamilton's data. Furthermore, the results appear to be due to a limited number of data points that involve, simultaneously, large movements in the Treasury balance and the federal funds rate. In addition, owing to the timing of the reserve maintenance period, the parameter estimates obtained by this procedure cannot reflect the coefficient λ in the transactions demand equation specified by Thornton. More likely they reflect some component of the demand for excess reserves. Again, Thornton does a persuasive job documenting the fragility of such results. One lesson to be drawn here is that any estimates of "structural parameters" based on the daily federal funds market must carefully consider the institutional detail of the market and how it changes over time. By and large, both Hamilton and Thornton exhibit such care, though what one obtains from one sample period may still not match what one obtains from another.

As an alternative methodology, Thornton suggests estimating λ by regressing nonborrowed reserves on the target level of the funds rate. In the context of this simple model, such a procedure implies estimating the relationship between B_t and $\bar{r}_t$ embedded in equations (3) and (4):

$$(7) \qquad B_t = -\lambda \bar{r}_t + \omega_t .$$

In the data, we should add suitable controls for other variables such as the discount-window borrowing that modify the relationship between nonborrowed reserves and the target funds rate. Thornton does more than that, however, adding both levels and changes in the target along with a host of right-hand-side variables, only some of which are justified by his model. While comprehensive, such an all-inclusive approach makes it difficult to get a solid fix on λ. At best, we can hope to identify the negative relationship implied by the theory. In the rest of my discussion, I wish to consider an alternative source of bias that could make estimation of equation (7) difficult.

A MODEL WITH PARTIAL ADJUSTMENT

Consider a slight variant on the OMD's operating procedure that allows for partial adjustment along the lines considered by Taylor (2001) also found in this volume:

$$(8) \quad B_t - B_{t-1} = \alpha\left(B_t^* - B_{t-1}\right) + \left[\alpha\omega_t + \left(1-\alpha\right)\Delta\omega_{t-1}\right].$$

The first term on the right-hand side of equation (8) implies that the OMD does not immediately close the gap between desired and actual nonborrowed reserves, but does so with some adjustment process. Although not motivated through an explicit theory based on loss-functions, Taylor argues that such a model provides a reasonable approximation to the actual operating procedures of the OMD. The second term on the right-hand side implies that the OMD fully responds to control errors, ω_t. This can be seen by rearranging equation (8),

$$B_t - B_t^* - \omega_t = -\left(1-\alpha\right)\Delta B_t^* + \left(1-\alpha\right)\left(B_{t-1} - B_t^* - \omega_{t-1}\right),$$

and solving backwards to obtain

$$(9) \qquad B_t = B_t^* - \left(1-\alpha\right)\sum_{i=0}^{\infty}\left(1-\alpha\right)^i \Delta B_{t-i}^* + \omega_t .$$

Equation (9) implies a slow adjustment of B_t to changes in the desired level of nonborrowed reserves—when B_t^* rises by one percent, B_t increases by the fraction α. Over time, B_t will rise by an additional $(1-\alpha)$ percent so that B_t and B_t^* track each other at a longer horizon. Given monetary policy, $B_t^* = -\lambda\bar{r}_t$, we obtain reduced-form expressions for both B_t and r_t:

$$(10) \qquad B_t = -\lambda\bar{r}_t + \lambda\left(1-\alpha\right)\sum_{i=0}^{\infty}\left(1-\alpha\right)^i \Delta\bar{r}_{t-i} + \omega_t$$

$$(11) \quad r_t = \bar{r} - \left(1-\alpha\right)\sum_{i=0}^{\infty}\left(1-\alpha\right)^i \Delta\bar{r}_{t-i} + \frac{1}{\lambda}\left(\nu_t^d - \nu_t^s - \omega_t\right).$$

There are two important implications that can be obtained from these expressions. First, the interest rate equation implies that deviations of the overnight rate from its target, $r_t - \bar{r}_t$, will be positively correlated if the target level displays persistence. This is a realistic feature of the data, documented by Balduzzi, Bertola, and Silvero (1997) and more recently by Taylor (2001).[1] In the extreme case of full adjustment, $\alpha = 1$ and deviations of the funds rate from its target are i.i.d. as in Thornton's model. This restriction is clearly at odds with the data, however.

The second important implication is that a regression of nonborrowed reserves on the federal funds target will yield a biased estimate of λ. To see this, suppose that the target rate follows an AR(1) stochastic process

$$(12) \qquad \bar{r}_t = \rho\bar{r}_t + \varepsilon_t$$

and consider estimating the following regression:

$$(13) \qquad B_t = \theta\bar{r}_t + u_t .$$

In this case, one can show that

$$(14) \qquad p\lim\left(\hat{\theta}\right) - \lambda = \lambda\left(1-\rho\right)\frac{\left(1-\alpha\right)}{\left(1-\left(1-\alpha\right)\rho\right)} .$$

In the case that $\bar{r}_t$ is i.i.d., the bias is $\lambda(1-\alpha)$, which depends on the degree of partial adjustment of B_t to B_t^*. In the case that $\bar{r}_t$ is a random walk, the bias is zero since the parameter estimate is superconsistent. More generally, the fact that r_t is stationary, but changes in discrete intervals at discrete points in time, suggests that the bias could vary substantially across sample periods. Finally, assigning the bias (and interpreting coefficient values) will be even more complicated when both the change and the level of the target funds rate are included on the right-hand side of the regression.

In summary, developing a complete structural model of the daily reserves market seems like a

[1] Both papers obtain a daily autocorrelation coefficient on the order of 0.4, implying a reasonable degree of persistence in daily data.

worthy goal. Understanding daily movements in the federal funds market and the link between open market operations and monetary policy actions requires the correct specification of all the structural equations that describe this market. The results in Thornton's paper suggest to me that one cannot identify structural parameters associated with the liquidity effect without taking into account all the equations in the system. In particular, the fact that the interest rate equation in Thornton's model is clearly misspecified implies that other equations in the reduced-form system are also likely misspecified. These insights can be used to modify and refine the model, however. In addition to providing a very useful analysis of past work using daily data to identify the liquidity effect, Thornton's paper sets us on a path toward such refinements.

Finally, I wish to end with a note of caution. The elasticity of money demand to interest rates that enters the dynamic general equilibrium models discussed above is not directly linked to the demand for reserves by banks on a daily or weekly basis. In particular, the elasticity of demand for reservable deposits by banks represents a short-run elasticity that may not say very much about the costs and benefits to firms and households of switching between money and alternative assets in response to changes in nominal interest rates. Although clearly interrelated, it is presumably the firms' and households' demand for real balances rather than the banking sector's demand for reserves that Milton Friedman referred to when coining the term "liquidity effect."

REFERENCES

Balduzzi, Pierluigi; Bertola, Guisseppe and Foresi, Silverio. "A Model of Target Changes and the Term Structure of Interest Rates." *Journal of Monetary Economic*, July 1997, *39*(2), pp. 223-49.

Bernanke, Ben S. and Blinder, Alan S. "The Federal Funds Rate and the Channels of Monetary Transmission." *American Economic Review*, September 1992, *82*(4), pp. 901-21.

Christiano, Lawrence J. and Eichenbaum, Martin. "Liquidity Effects in the Transmission of Monetary Policy." *American Economic Review*, May 1992, *82*(3), pp. 346-53.

___________ and ___________. "Liquidity Effects, Monetary Policy, and the Business Cycle." *Journal of Money, Credit and Banking*, November 1995, *27*(4, Part 1), pp. 1113-36.

Hamilton, James D. "Measuring the Liquidity Effect." *American Economic Review*, March 1997, *87*(1), pp. 80-98.

Taylor, John. "Expectations, Open Market Operations, and Changes in the Federal Funds Rate." Federal Reserve Bank of St. Louis *Review*, July/August 2001, *83*(4), pp. 33-48.